Chapter: Semiconductor

P-N Junction:

When a P-type semiconductor is joined to N-type semiconductor, junction is formed which is called P-N Junction. . Practically, the two regions are created side by side in the same piece of semiconductor. P-N junction is a fundamental building block of many other semiconductor electronic devices such as diode, transistors, solar cells, light emitting diodes (LED), and integrated circuits.

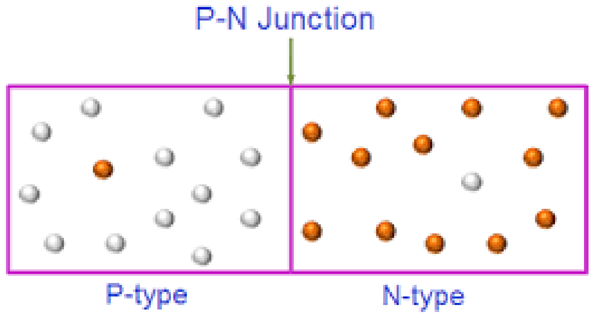
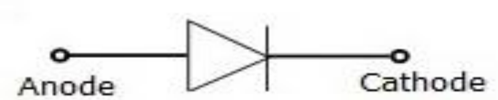


fig P-N junction

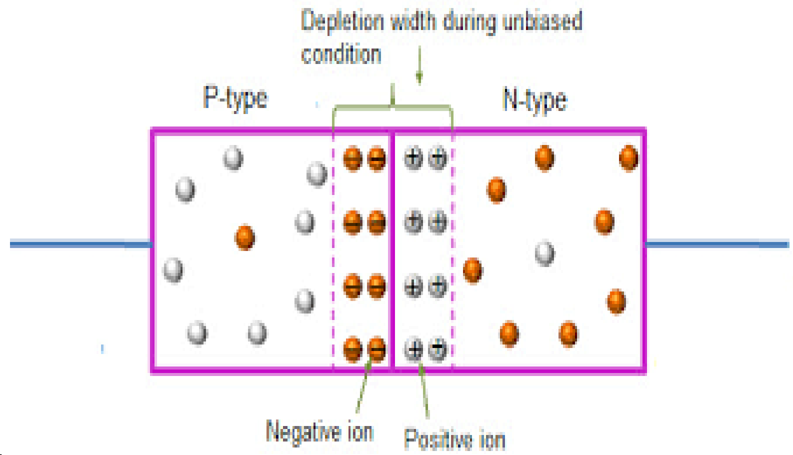
P-N Junction Diode (Semiconductor Diode)

When a pure form of semiconductor is doped with P-type material at one end and N-type material at another end, the resulting semiconductor material is called P-N junction diode. It consist of two electrodes i.e. anode and cathode. The anode refers to P-type region and the cathode refers to N-type region. It acts like a one way conductor. The arrow head shown in the circuit symbol, points the direction of current flow when it is forward biased.



DEPLETION LAYER & POTENTIAL BARRIER:

In P-N Junction, the Holes are the majority charge carriers in P region & that of electrons in N-region. The Holes diffuse from P to N region & electrons from N to P region. The Holes &electrons recombine & terminate their existence at the Junction. The recombination of mobile Holes & free electrons produce the narrow region (layer) at the junction is called Depletion layer. The depletion layer is the charge-empty region. But it contains fixed positive & negative ions called Dipoles .The thickness of depletion layer is of the order of few microns (10-6m). The potential developed across the P-N Junction due to the migration of electrons into the P-region & Holes into the Nregion is called Barrier Potential (VB). VB= 0.3V for germanium & 0.7V for Silicon. The Barrier potential depends upon Doping density, electronic charge, temperature etc. When temperature increases,



Barrier potential decreases & vice-versa.

BIASING OF P-N JUNCTION DIODE:

The process of applying the potential difference across P-N Junction Diode for their proper working is called Biasing of the diode. It is the operating process of diode due to the application of electric field on it.

TYPES OF BIASING OF DIODE:

Forward Biasing:

The process of connecting P-side of junction with positive terminal & n-side with negative terminal of a battery is called Forward Biasing. In this biasing, the negative terminal of a battery repels the free electrons in the N-region towards the Junction & the positive terminal on P-region pushes the holes towards the junction. The free electrons & holes combine & current flows through the diode. Basic

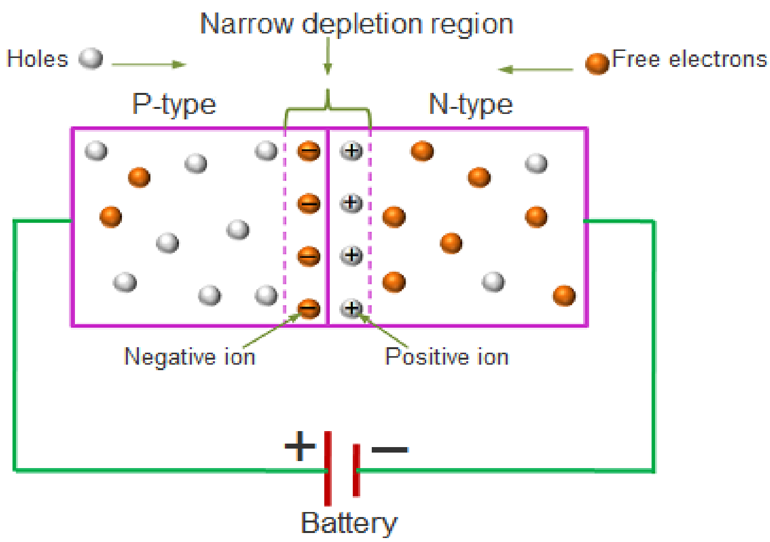


fig. forward biasing

Features of forward biasing:

• The width of the depletion layer decreases

• The barrier potential is reduced

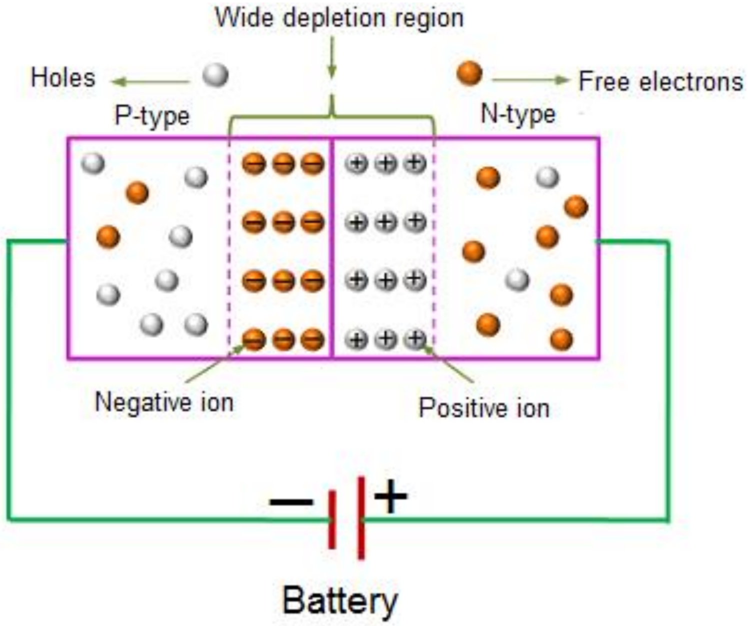
• The diode acts as closed circuit

• The diode offers very low resistance (called Forward resistance)

• The high current flows through the diode due to majority charge carriers.

REVERSE BIASING:

The process of connecting P-side of junction with negative terminal & N-side with the positive terminal of a battery is called Reverse Biasing. In this biasing, the electrons from N-region are attracted towards the positive terminal & holes in the P-region are attracted towards the negative terminal of the battery. The departing electrons leaves more positive ions near junction & departing holes leaves more negative ions & width of depletion layer increased. So only small current flow due to minority charge carriers.



Basic features of reverse biasing:

- The width of the depletion layer increases.
- The barrier potential is increased.
- The diode acts as open circuit
- The value of reverse current is negligibly small called Leakage current.
- The diode offers very high resistance (called Reverse resistance) to allow current.
- The less current flows through the diode due to minority charge carriers.

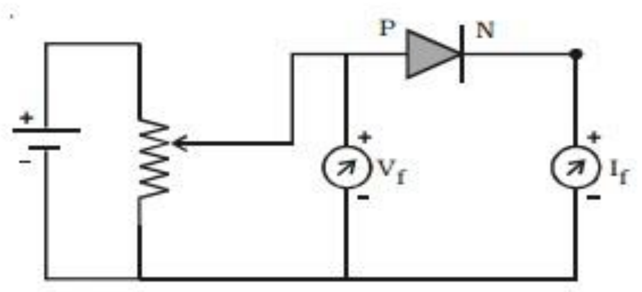
CHARACTERISTICS OF JUNCTION DIODE:

The graphical relationship between current & voltage across the junction diode is called Characteristics of the junction diode. It is also known as I-V characteristics of the Junction Diode.

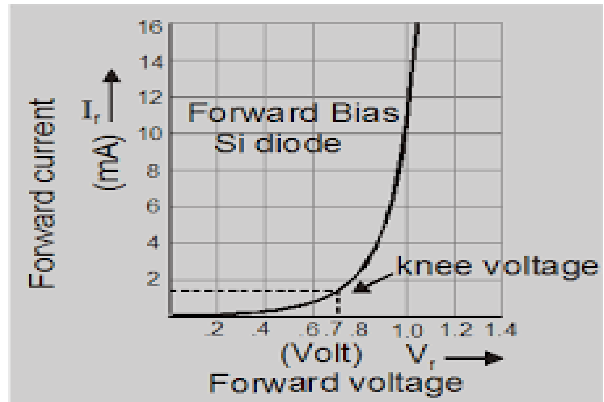
a) **Forward characteristics:**

The graphical relation between Forward current & forward voltage of the junction diode is known as forward characteristics of junction diode. Figure shows the circuit arrangement of the forward characteristics of a diode. The voltmeter (V) measures the potential difference across the diode and milli-ammeter (mA) measures the current flows through it. The forward voltage V_F across the diode is varied with the help of rheostat R_h and the corresponding diode current I_F is noted. A graph of V_F versus I_F is shown in figure. This graph represents the forward characteristics of the diode.

When the applied voltage is small in forward biasing, a small current flows through the diode. As the voltage is increased, the current through the diode is also increased. *The forward voltage at which the diode current increases rapidly or sharply is called knee voltage* V_k The knee voltage is equal to the barrier potential of the diode which is about 0.7 V for silicon and 0.3 V for germanium.



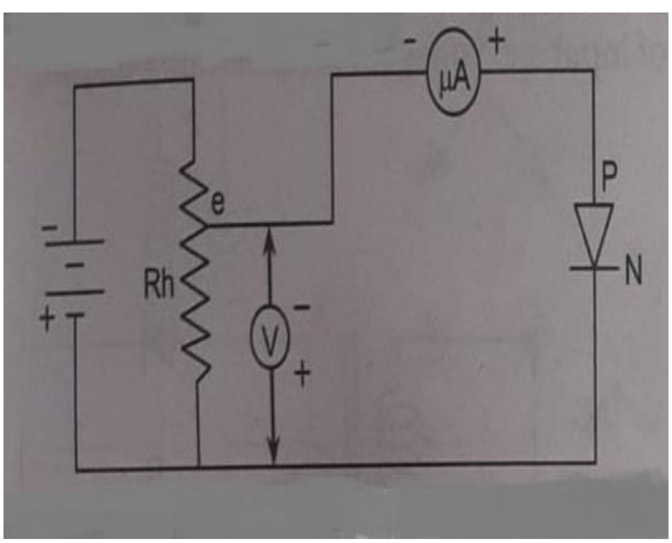
(a) Diode circuit–Forward bias



b) Reverse characteristics:

It is the graph showing the variation of reverse current with reverse voltage. The circuit diagram for the reverse characteristics of the diode is shown in figure. The voltmeter (V) measures the reverse voltage and micro-ammeter (μA) measures the reverse current flowing through the diode. The reverse voltage across the diode V_R is varied with the help of rheostat R_h and the corresponding reverse current I_R is noted by micro-ammeter. A graph of I_R versus V_R is shown in figure, which represents the reverse characteristics of the diode.

When the diode is reverse biased, the majority charge carriers are blocked and only a small current flows through the diode due to minority carriers. As the high reverse voltage is applied, the diode current begins to increase sharply. *The reverse voltage at which the diode current starts to increase sharply is called break down voltage* V_b. The break down voltage depends on the density of dopants and the thickness of depletion region.



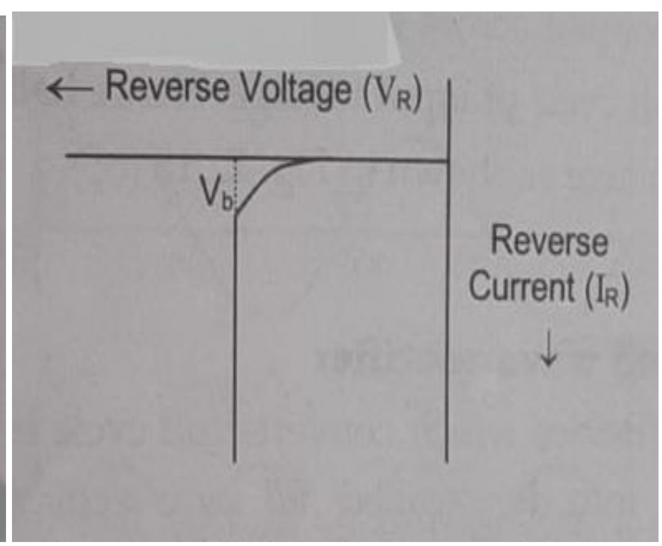


Fig. Circuit diagram for reverse characteristics

Fig. Reverse characteristics

Rectification and Rectifier

The process of converting ac signal into dc is called rectification. An electronic device which is used for rectification is called rectifier. When P-N junction diode is forward biased, it offers low resistance and current flows through it. But when reverse biased, it offers high resistance and no current flows through it. This unidirectional current conducting property of a junction diode is used in rectification. There are two types of rectifiers.

1) Half-wave Rectifier (HWR)

2) Full Wave Rectifier (FWR): It is also of Two types

   a) Centre Tapped Full Wave Rectifier

   b) Bridge Rectifier (Full Wave Bridge Rectifier)

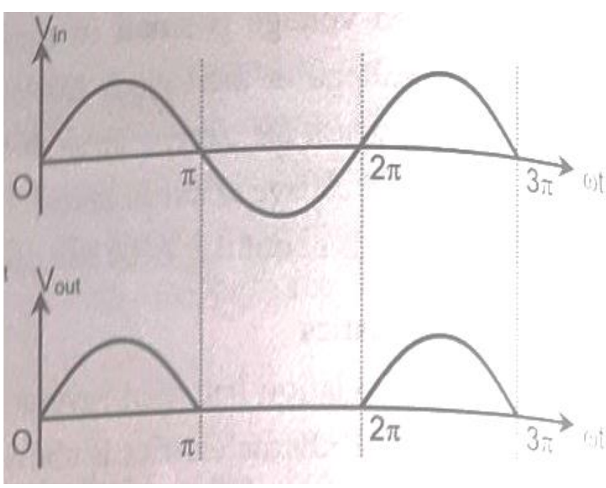
HALF-WAVE RECTIFIER:

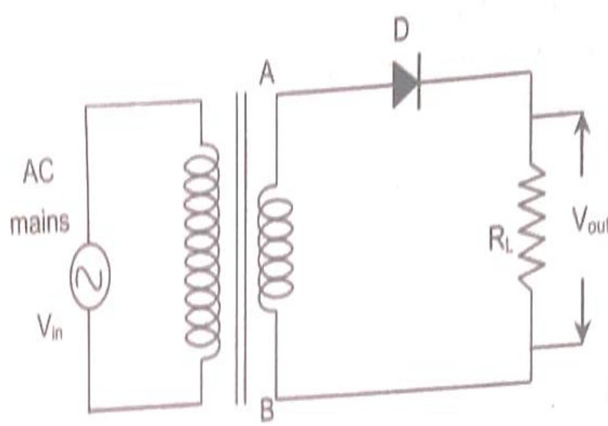
[Describe with a neat diagram the working mechanism of halfwave rectifier for a junction diode.

➢A device which rectifies only one half cycle of ac into dc is called Half-Wave Rectifier. A single junction diode can be used as a half-wave rectifier. Half-wave rectifier consists of a Transformer, a diode (D) & a load resistance (R_L) (shown in fig1). The primary coil of a transformer is connected to ac mains supply & secondary coil is connected to the Load resistance through the diode.

During Positive half cycle of input Voltage Vin, the diode D is forward biased (ON) & it conducts. The current flows in the circuit & output voltage V_{out} is dropped across R_L.

During Negative Half cycle of input Voltage Vin, the diode D is Reverse biased (OFF) & no voltage is dropped across R_L. The current blocks & doesn't conduct. Hence current only flows through positive half cycle & Halfwave of input ac voltage is rectified into pulsating dc voltage (fig2). Thus a single P-N Junction diode acts as a Half-Wave Rectifier.





FULLWAVE RECTIFIER:

➢ A device which converts full cycle of ac into dc is called full wave rectifier. There are two types of full wave rectifier. They are

i) Center Tapped Full Wave Rectifier and

ii) Bridge Rectifier

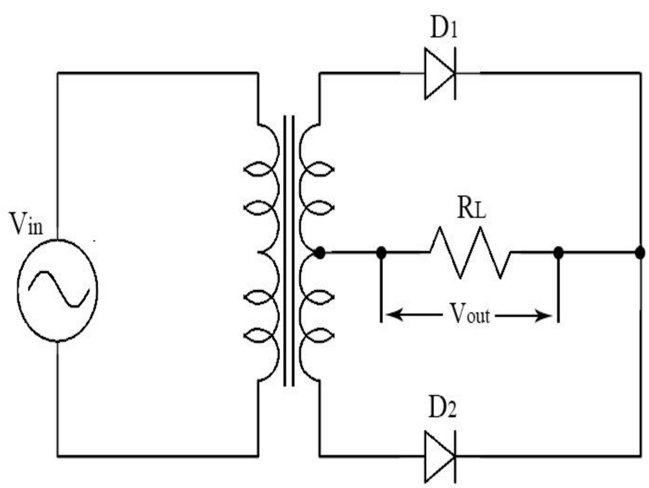
Center Tapped Full Wave Rectifier

[**How can you construct a full-wave rectifier using two semiconductor diodes? Explain their working.] Or [Describe the working of full-wave rectifier using the two semiconductor diodes]**

The circuit diagram for full wave rectifier is shown in figure. It consist of a transformer, two diodes and load resistance. The diodes D_1 and D_2 are connected to the centre tapped secondary coil of a transformer trough the load resistance R_L.The diodes are connected in such a way that they conduct during alternate half-cycles of the input or supply voltage.

During the positive half cycle of input voltageV_{in}, the upper end of secondary coil is positive with respect to lower end then the diode D_1 is forward biased and D_2 is reverse biased. So, D_1 conducts and D_2 is off.

During negative half cycle, the upper end of secondary coil is negative with respect to lower end then the diode D_1 is reversed biased and D_2 is forward biased. So, D_2 is on and D_1 is off. In both half cycles, unidirectional current flows through R_L. The half wave is rectified by D_1 and next half wave is rectified byD_2. Thus the combination of D_1 and D_2 works as full-wave rectifier. The input and output wave form of center tapped Full wave rectifier is shown in figure (b).



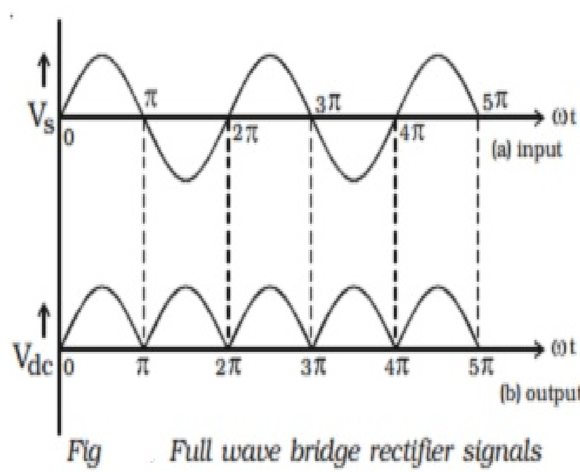


Figure (a) : Circuit diagram of full wave rectifier Figure (b) : Input and output voltage in full wave rectifier

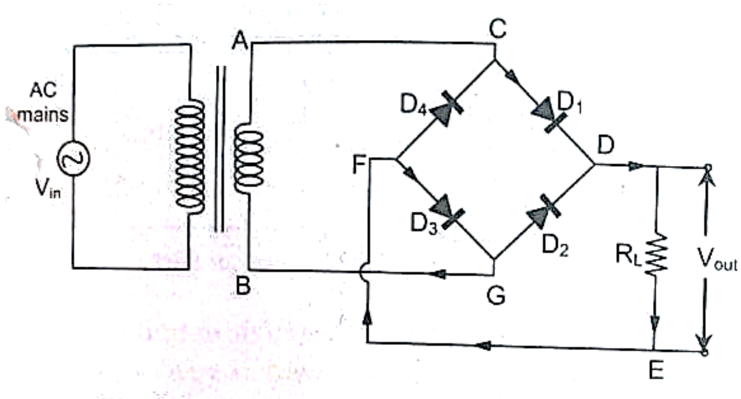
FULL-WAVE BRIDGE RECTIFIER or BRIDGE RECTIFIER:

Describe the working of full-wave rectifier using the four semiconductor diodes] (4 marks)

A Full-Wave Rectifier in the form of Bridge is called Bridge Rectifier. It converts full cycle of ac into dc. It consists of four diodes D_1, D_2, D_3 & D_4 & a load resistor RL. The diodes are connected in such a way that two diodes conduct during Positive half-cycle & other two diodes conduct during Negative Half Cycle.

During positive half cycle, the terminal A is positive & B is negative. The diodes D_1 & D_3 becomes forward biased whereas the diodes D_2 & D_4 are Reversed Biased. Hence current flows along ACDEHGFIB producing drop across RL.

During negative half cycle, the terminal A is negative & B is positive. The diodes D_2 & D_4 becomes forward biased whereas the diodes D_1 & D_3 are Reversed Biased. Hence current flows along BIFEHGDCA producing drop across RL. In both Half cycles, Unidirectional current flows through RL. The first half cycle is rectified by diodes D_1 , D_3 & next half cycle by diodes D_2 , D_4 . In this way, the bridge rectifier acts as a Full Wave Rectifier.



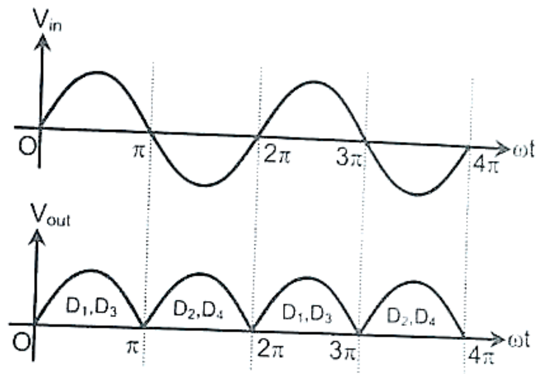


Fig: a) Circuit diagram of bridge rectifier b) Input and output voltage of bridge rectifier

Filter Circuit

Generally rectifier is needed to produce pure dc. However, the output of rectifier is pulsating dc with both ac and dc components. The ac component in the output is undesirable called ripple factor and must be removed from the output of rectifier. *A circuit which removes ac component in output of rectifier but allows the dc component to reach the load is called filter circuit.* The filter circuits converts pulsating dc into steady dc from the output of rectifier. The filter circuit is connected between the rectifier and the load as shown in figure. It consists of passive elements like capacitor, inductor or their combination. The most common filter circuits are as follows.

a) Capacitor filter

b) Inductor filter

c) LC filter

d) π- filter (CLC filter)

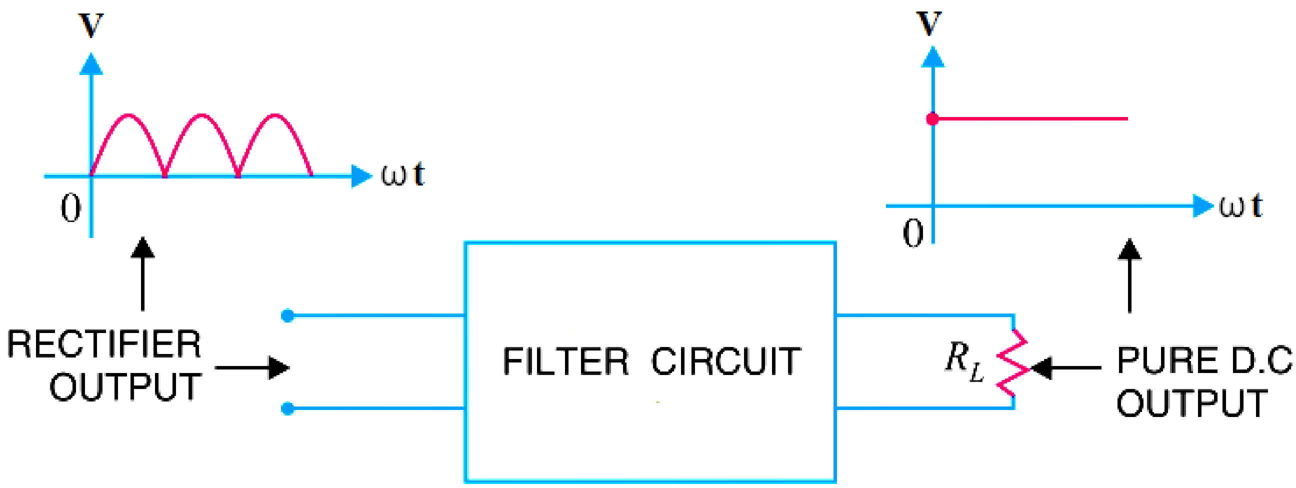


Fig: The conversion of pulsating dc into pure dc through a filter circuit

a) Capacitor filter

The circuit diagram for capacitor filter is shown in figure .It consist of a capacitor C connected across the rectifier output and load resistance.

Capacitive reactance $(X_C) = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

for dc, $f = 0$. So $X_C = \infty$

Inductive reactance $(X_L) = \omega L = 2\pi f L$

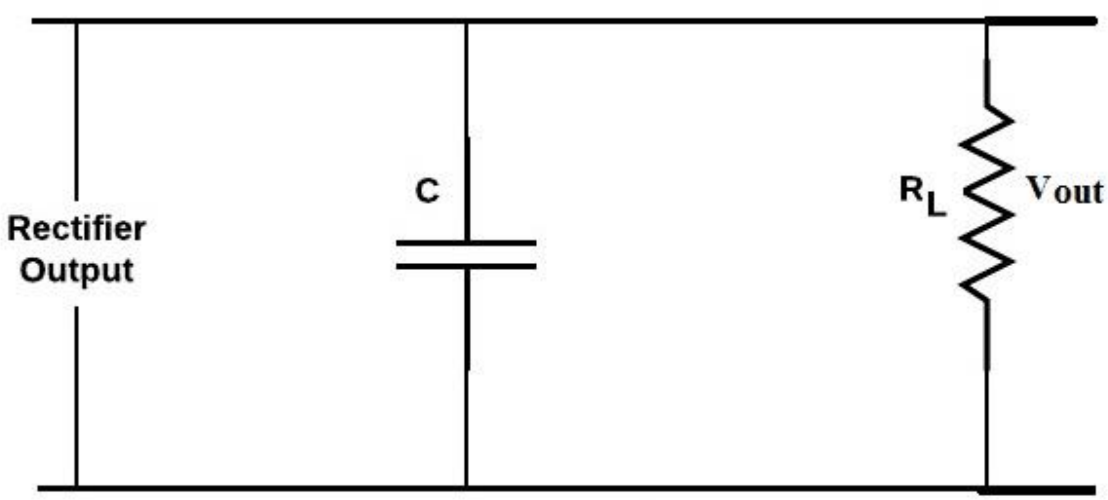


Fig. Capacitor filter circuit

The capacitor offers high resistance for dc and low resistance for ac components. Thus most of the ac components passes through the capacitor through the ground where as the dc component drops across the load. It is found that very little ripple is left in the output. It produces a dc output voltage equal to the peak value of the rectified voltage. This type of filter is widely used in power supplies.

b. Inductor filter circuit

The circuit diagram for inductor filter is as shown in figure. It consist of an inductor of inductance L is connected in series with load resistance. The inductor offers high resistance for ac but very low resistance to dc. The inductor blocks most of the ac components and very little ripple factor is left in the output.

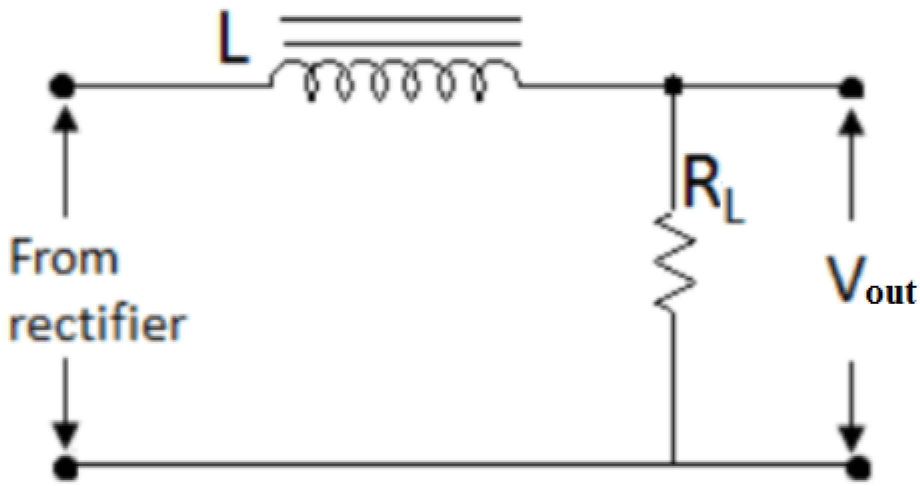


Fig. inductor filter circuit

c. LC filter (choke input filter) circuit

The LC filter circuit is shown in figure. It consist of an inductor of inductance L is connected in series with the output of the rectifier and the capacitor of capacitance C is connected parallel to the load resistance. In this filter, the inductive reactance is much greater than capacitive reactance. The inductor offers high resistance to ac and low resistance to dc component. Therefore, it blocks ac and allows dc to pass through it. On the other hand, the capacitor offers high resistance to dc and low resistance to ac component. Therefore a capacitor bypasses the ac which is not blocked by the inductor. Thus the output of this filter has very little ripple and good regulation. The LC filter is used as switching regulator in computers, monitors and different variety of equipments.

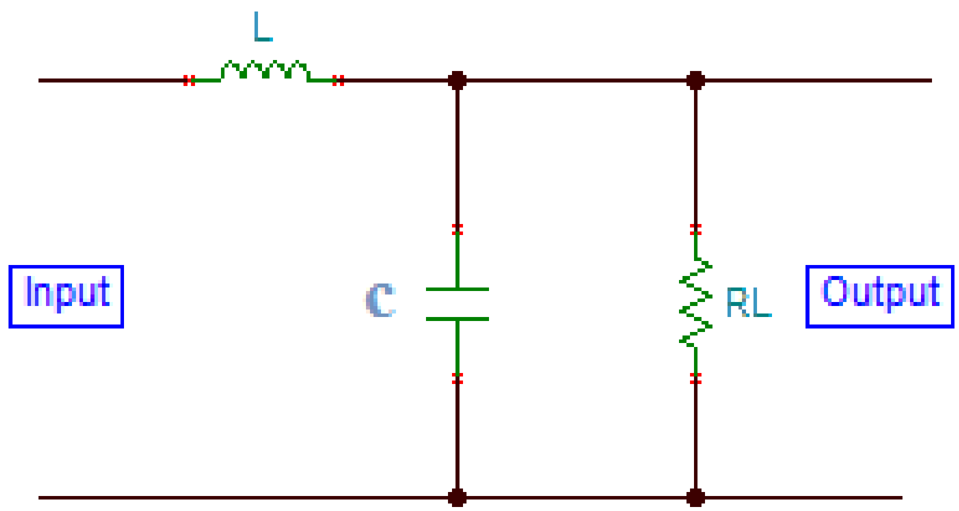


Fig. LC filter circuit

d) π-filter circuit

The circuit diagram for the π-filter is shown in figure. It consist of a filter capacitor C1 connected across the rectifier output, an inductor L in series and another capacitor C2 connected across the load resistance. The filtering action of each component of this filter circuit is described below.

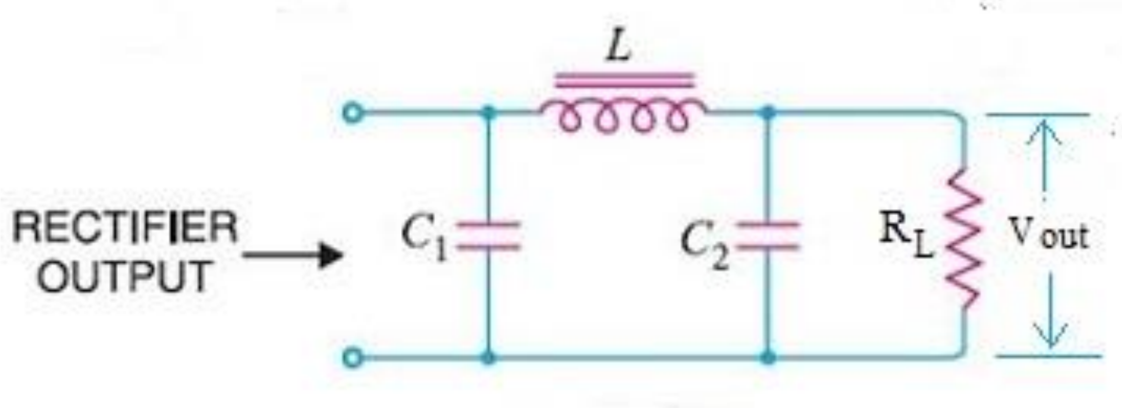


Fig. π-filter circuit

Capacitor C1

It offers low resistance to ac component and infinite resistance to the dc component of rectifier output. So, the capacitor C1 bypasses appreciable amount of ac to the ground where as the dc component flows towards the inductor.

Inductor L

The inductor offers very high resistance to ac and very low resistance to dc component of rectifier output. Therefore, it blocks ac and allows dc to pass through it.

Capacitor C2

Similarly, the capacitor C2 bypasses the ac component of rectifier output which is not blocked by the inductor and due to high resistance, dc component flows towards load resistance.

In this way, the π-filter blocks ac components to the output and the output nearly contains dc components. The π-filter circuit is better than other filter circuits. This filter is used in low-current equipment.

Reverse breakdown (Junction breakdown)

In reverse biased condition, junction diode allows very small current called reverse saturation current. This current is due to the movement of minority charge carriers across the junction and is in the range of Nano-ampere for silicon diode and micro-ampere for germanium diode. However, when the reverse voltage is applied beyond a particular value, the current rises sharply due to breakdown of diode. The junction breakdown is avoided in normal condition. There are two types of breakdown occurring in the junction diode.

1. Zener Breakdown

In a heavily doped junction diode, the depletion region is very narrow. When a reverse voltage is increased, the electric field at the junction also increases. When this field is about **10^8 V/m** , electrons are pulled out of the covalent bond. A large number of electrons holes pair are thereby created. The reverse current rises steeply. This is Zener effect or Zener breakdown.

2. Avalanche Breakdown

The reverse biased voltage applied across the diode accelerates the minority charge carriers in the depletion region. These carriers gain sufficient energy to ionize the atoms by collision. The electrons produced thereby accelerates sufficiently large velocities to be able to ionize other atoms. This creates a chain reaction. The cumulative effect of this chain reaction is the avalanche effect or **avalanche breakdown**.

A typical I-V characteristic curve showing forward current and reverse current in Zener and avalanche breakdown is as shown in figure.

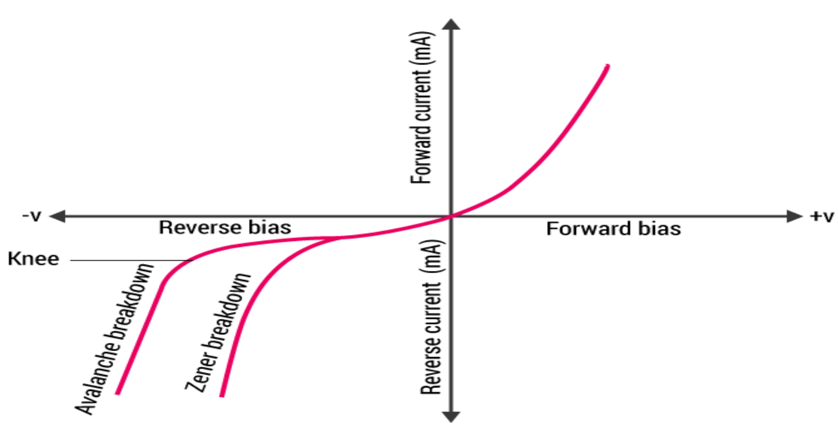


Fig. Reverse breakdown

Zener Diode

A Zener diode is a heavily doped p-n junction diode preferably a Silicon diode that operates in reverse bias condition in the reverse breakdown voltage region without being damaged, whereas a normal p-n junction diode operates in forward biased Condition only. The circuit symbol for Zener diode is as shown in figure.

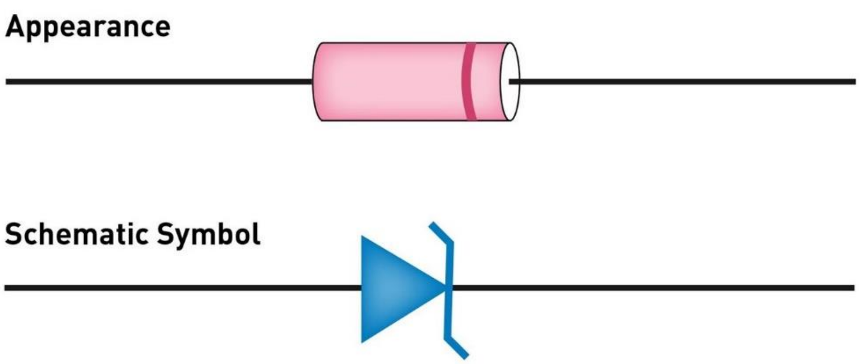


Fig. Zener Diode

Zener diode as voltage regulator

The device which is used to regulate the voltage is called voltage regulator. In voltage regulation, the circuit maintains constant output voltage although there is variation in input voltage or current and load resistance.

The zener diode can be used as a voltage regulator. It is also called voltage regulator diode. The circuit diagram of zener diode as voltage regulator is shown in Fig . It consist of a series resistance R_S, zener diode and load resistance R_L. The zener diode is connected parallel to the load resistance. The unregulated input voltage V_{in} is to be dropped across R_S and the output voltage V_o is to be regulated across R_L. The zener diode works only if the input voltage is greater than zener voltage V_Z (i.e. $V_{in} > V_z$).

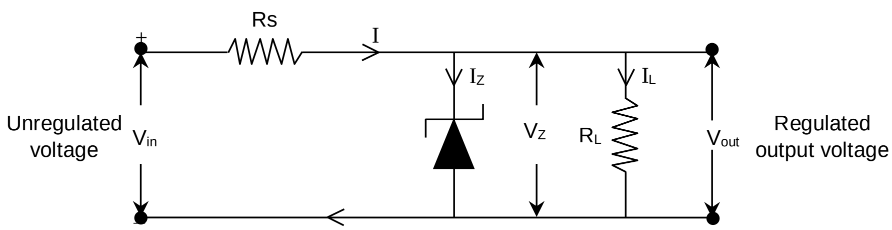


Fig *Circuit diagram of zener diode as a voltage regulator*

When the input voltage is lesser than zener voltage, no current passes through the diode (i.e. $I_z = 0$) and all of the input voltage drops across load resistance.

Here, $V_o = V_{in}$ at $I_z = 0$.

When $V_{in} = V_Z$, the breakdown point is reached and voltage across the diode is constant.

When $V_{in} > V_{Z,}$ the output voltage remains constant but there is increase in voltage across R_S. Hence the voltage is regulated.

The current through R_S is,

$I = (V_{in} - V_Z) / R_S$

Thus, total current (I) = $I_Z + I_L$

Regulation with varying input voltage.

When the input voltage increases the input current I also increasos. This increases the current through the zener diode Iz without affecting the load current I_L. The increase in input current will also increase the voltage drop across the series resistance R_S thereby keeping the load voltage as constant. On the other hand, if the input voltage is decreased, the input current also decreases As a result of this, the current through the zener diode will also decrease Consequently, the voltage drop across series resistance will be reduced. Thus the load voltage V_L and load current I_L remains constant.

Regulation with varying load resistance.

When the load resistance R_L decreases, the load current I_L increases. This causes the zener current to decrease. As a result of this, the input current and the voltage drop across the series resistance remains constant. Thus the load voltage V_L is also constant. On the other hand, if the load resistance increases, the load current decreases. As a result of this the zener current I_z increases. This again keeps the value of input current and voltage drop across series resistance as constant. Thus the load voltage remains constant.

Transistor

Transistor is a three terminal electronic device formed by the combination of two p-n junction diode in specific manner. It is also called bipolar junction diode. They are used to amplify or switch electric signal and electric power.

There are three doped regions in a transistor called emitter E, base B and collector C as shown in Fig-

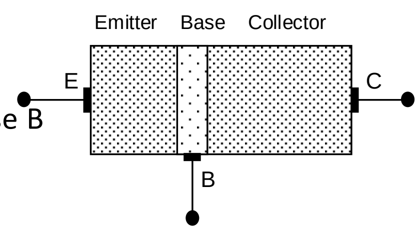


Fig-: *Transistor*

Emitter

The left hand section of transistor is called emitter (E). It is more heavily doped region. It is thicker than base but thinner than collector as shown in Fig. The main function of this region is to emit or supply majority charge carriers to the base.

Base

The middle region of transistor is called base (B) as shown in Fig. The main function of base is to pass large number of charge carriers from emitter to the collector region. The base is made thin and is lightly doped to minimize the recombination of electrons and holes so that large numbers of majority charge carriers reach the collector.

Collector

The right hand section of transistor is called collector as shown in Fig. It is the largest region of a transistor. It is moderately doped region. Its doping level is in between those of emitter and base. The main function of collector is to collect majority charge carriers through the base.

Types of transistor

There are two types of transistor.

1. npn Transistor
2. pnp Transistor

npn transistor

The transistor in which emitter and collector regions are n-types and base region is p-type semiconductor is called *npn transition*. In this transistor, the majority charge carriers are the electrons. In the electronic symbol of transistor, the arrow always represents the emitter terminal. In npn transistor, the arrow points outwards.

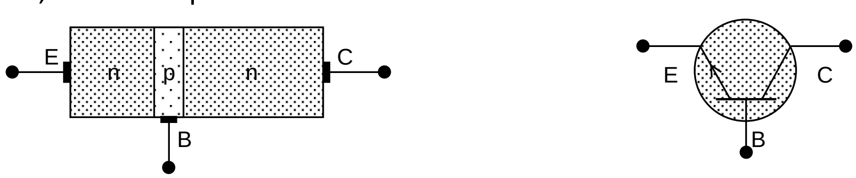


Fig: *(a) Block diagram of npn transistor (b) Electronic symbol of npn transistor*

pnp transistor

The transistor in which emitter and collector regions are p-types and base region is n-type semiconductor is called *pnp transition.* In this transistor, the holes are the majority charge carriers. In the electronic symbol of pnp transistor, the arrow points inward i.e. “pointing in” as shown in Fig.

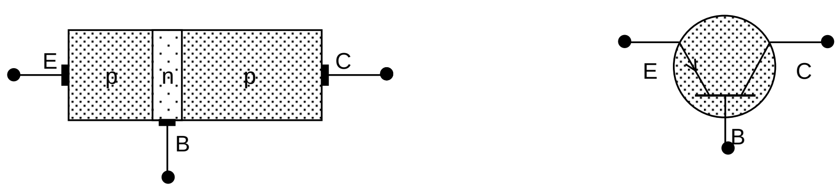


Fig: *(a) Block diagram of pnp transistor (b) Electronic symbol of pnp transistor*

Logic Gates

The electronic circuit which makes logic decision is called *logic gate*. These are building blocks of digital electronics. Logic gate is a switching circuit which can be realized by using semiconductor devices.The functions of logic gates are based on Boolen algebra. A logic gate has two or more inputs but only one output. Every input variable in a logic gate is either 0(low) or 1 (high). But the output depends on the input signals and type of gate. There are two type logic gates.

A. Basic (or simple) logic gates   B. Compound logic gates

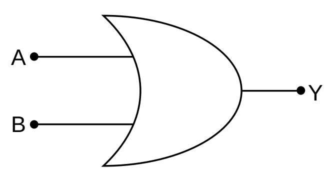
A. Basic logic gates:

There are three basic gates:

i) OR gate   (ii) AND gate   (iii) NOT gate

OR Gate:

The gate whose output is high i.e. 1 if any or all inputs are high is called *OR gate*. It has two or more inputs but only one output. Let A and B represent two inputs and Y is the output. The Boolen expression for OR gate is, Y = A + B. The logic symbol, realization circuits and practical circuit diagram of two input OR gate are shown in Fig.



Logic symbol

Fig: *OR Gate*

The operation of OR gate is as follows:

1. When both A and B are low, Y is low
2. When A is high and B is low, Y is high.
3. When A is low and B is high, Y is high.
4. When both A and B are high, Y is also high.

The truth table of OR gate is given below.

Inputs		**Output y**
A	**B**	
0	0	0
1	0	1
0	1	1
1	1	1

AND Gate

The logic gate whose output is high i.e. 1 when all the inputs are high is called AND gate. It has two or more inputs but only one output. Let A and B represents two inputs and Y is the output. The Boolen expression for AND gates is,   Y = A. B

Logic symbol

The logic symbol, realization circuit and practical circuit diagram of two input AND gate are shown in Fig-22.43.

Fig: *AND Gate*

The operation of AND gate can be discussed in following four cases.

1. When both A and B are low, Y is low
2. When A is high and B is low, Y is low.
3. When A is low and B is high, Y is low.
4. When both A and B are high, Y is also high.

Truth Table of AND gate		
Inputs		**Output Y**
A	**B**	
0	0	0
1	0	0
0	1	0
1	1	1

NOT Gate

The gate whose output is high i.e. 1 when the input is low i.e. 0 is called *NOT gate*. It is also known as *inverter* because the output is always the complement of input. It has only one input an only one output.

Let A be the input and Y be the output. The Boolen expression for NOT gate is, $Y = \overline{A}$
The logic symbol, realization circuit and practical circuit of NOT gate are shown in Fig.

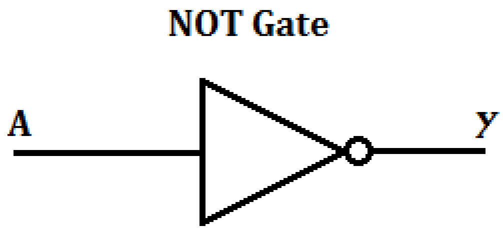


***Fig:** NOT Gate*

The operation of NOT gate is as follows.

1. When A is low, y is high.
2. When A is high, y is low.

The truth table for NOT gate is given below.

Input	Output
0	1
1	0

B. Compound logic gates

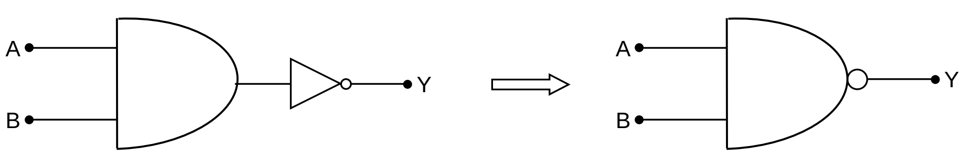
The compound gates are formed by the combination of two or more basis gates OR, AND and NOT gates. There gates give rise to the complicate digital circuits. The different types of compound gates are as follows:

i) NAND gate
ii) NOR gate
iii) X OR gate
iv) X NOR gate
v) Bubbled OR gate
vi) Bubbled AND gate etc.

Of the above logic gates, we will discuss only first two.

NAND gate

The combination of AND gate and NOT gate is called NAND gate. This gate is designed in such a way that the output of AND gate is connected to the input of NOT gate. It has two or more inputs but only one output. In this gate, the output is low if all of its inputs are high. The logic symbol of two inputs NAND gate is shown in Fig.



NAND Gate Logic symbol

Fig: *NAND Gate*

Let A and B represent the inputs and Y represents the output of NAND gate. The Boolen expressions for NAND gate is

$$Y = \overline{A.B}$$

Operation of NAND gate

The operation of NAND gates is as follow

1. When both A and B are low, Y is high.
2. When A is high and B is low, Y is high.
3. When A is low and B is high, Y is high.
4. When both A and B are high, Y is low.

The truth table of NAND gate is given below:

Inputs		**Output** $Y = \overline{A.B}$
A	**B**	
0	0	1
1	0	1
0	1	1
1	1	0

NAND Gate as Universal Gate

NAND Gate is universal gate.The repeated use of this gate can produce all the three basic gates i.e. OR, AND and NOT gates. This gate serves as a building block in digital circuits.

1) **NOT gate from NAND gate:**

Not gate can be made from NAND gate by connecting its two inputs together as shown in Fig. The output is $\overline{A.A}$ which can be proved to be equal to $\overline{A}$ by using Demorgan's theorem.The truth table also verifies this fact.

Truth table of NOT gate

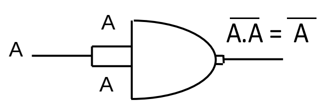


***Fig:** Logic symbol of NOT gate by using NAND gate*

Inputs		Output Y = $\overline{A}$
A	**B = A**	
0	0	1
1	1	0

2. AND gate form NAND gates

Two NAND gates are used to produce AND gate as shown in Fig. The output of first NAND gate $\overline{A.B}$ is given to the second NAND gate acting as inverter. The final output is inverted and is given by Y = $\overline{\overline{A.A}}$ = A.B which is the logic function of AND gate. This fact is also verified by the truth table.

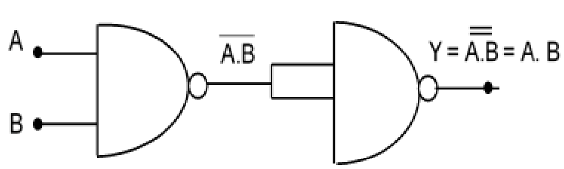


Fig Logic symbol of AND gate by using NAND gates

Truth table of AND gate

A	B	$\overline{A.B}$	Y = A.B
0	0	1	0
1	0	1	0
0	1	1	0
1	1	0	1

3. **OR gate form NAND gates:**

Three NAND gates are used to produce OR gate as shown in Fig . The first two NAND gates are acted as NOT gates and their output are fed to the third NAND gate. The final output is $\overline{A}\,\overline{B}$ which can be prove to be equal to A + B by using Demorgan's theorem. This fact is also verified by truth table.

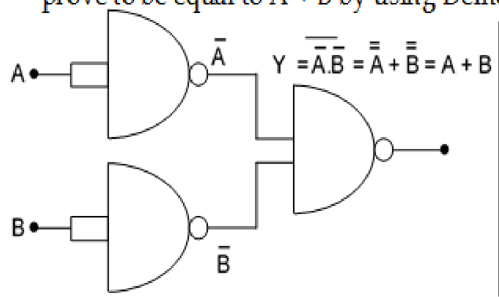


Fig Logic symbol of OR gate by using NAND gates

A	B	$\overline{A}$	$\overline{B}$	$Y = \overline{\overline{A}} + \overline{\overline{B}} = A + B$
0	0	1	1	0
1	0	0	1	1
0	1	1	0	1
1	1	0	0	1

NOR Gate

The combination of OR gate and NOT gate is called NOR gate. This gate is design in such a way that the output of OR gate is connected to the input of NOT gate. It has two or more inputs but only one output.In this gate, the output is high (1) when all inputs are low (0). The logic symbol of NOR is shown in Fig.

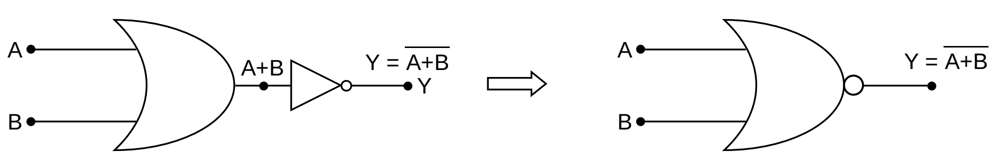


Fig:Logic symbol of NOR gate.

If the A and B represent the inputs and y represents the output of NOR gate then, Boolen expression for NOR gate is, $Y = \overline{A + B}$

Operation of NOR gate:

The operation of NOR gate is as follows:

1. When A and B both low, Y is high.
2. When A is high and B is high, Y is low.
3. When A is low and B is high, Y is low.
4. When A and B both high, Y is low.

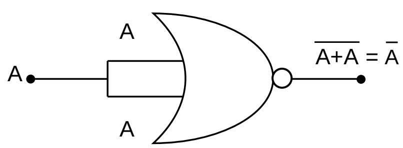
Truth for NOR gate		
Inputs		**Output** $Y = \overline{A+B}$
A	**B**	
0	0	1
1	0	0
0	1	0
1	1	0

NOR Gate as Universal Gate

The repeated use of NOR can produce all three basic gates like OR, AND and NOT gates. Therefore NOR gate is also called universal gate. This gate acts as building block in digital circuits.

1. **NOT gate from NOR gate:**

   Not gate can be produced from NOR gate by connecting its two inputs together as shown in Fig. The output is $\overline{A+A}$ which can be proved to be equal to $\overline{A}$ by using Demorgon's theorem. The truth table also verifies this fact.



Logic symbol

Fig: *Logic symbol of NOT gate by using NOR gate*

Inputs		**Output** $Y = \overline{A}$
A	**B(=A)**	
0	0	1
1	1	0

2.OR gate from NOR gate:

Two NOR gets are used to makes OR gate as shown in Fig. The output of first NOR gate i.e. $\overline{A+B}$ is given to the second NOR gate which acts as inverter.The final output is inverted and is given by Y = A + B which is the logic function of OR gate. This fact is also verified by truth table.

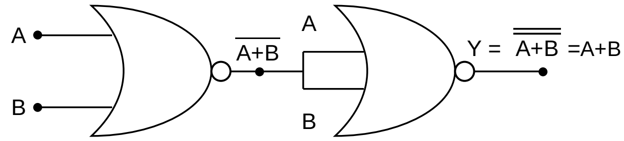


Fig: *Logic symbol of OR gate by using NOR gate*

Inputs		$\overline{A+B}$	$Y = \overline{\overline{A+B}} = A + B$
A	**B**		
0	0	1	0
1	0	0	1
0	1	0	1
1	1	0	1

3. AND gate from NOR gate:

Three NOR gates are used to make AND gate as shown in Fig. The first two AND gates are operated as NOT gates and their outputs are fed to the third NOR gate. The final output is Y= $\overline{\overline{A}+\overline{B}}$, whichcan be proved to be equal to A.B with the help of Demorgan's theorem. The truth table also verifies this fact.

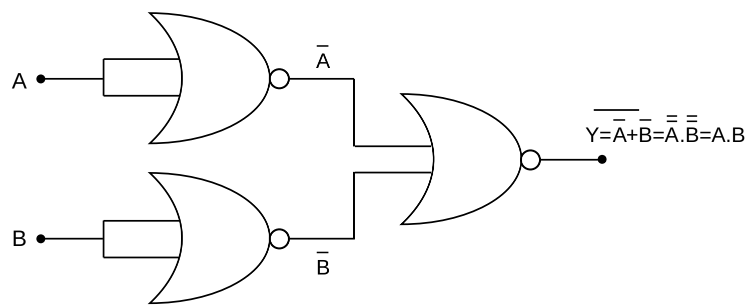


Fig:*Logic symbol of AND gate by using NOR gate*

A	**B**	$\overline{A}$	$\overline{B}$	$Y = \overline{\overline{A} + \overline{B}} = A . B$
0	0	1	1	0
1	0	0	1	0
0	1	1	0	0
1	1	0	0	1

Nanotechnology

Nanotechnology is a branch of science which deals with the size of the particles in the range of 1 to 100 nanometers. Nanotechnology is the study of matter on an atomic and molecular scale. It involves developing new materials, devices and system within the range of nano scale. The properties of bulk materials are mostly retained when their dimensions reduce to micrometer range. However the materials in nano scale called nanomaterial's show remarkably new properties. The nano materials are size dependent and they exhibit quantum size effect. The number of physical properties such as mechanical, electrical, optical etc. change as compared to macroscopic system. For example, opaque substance (i.e. copper) can becomes transparent, insoluble materials (gold) may become soluble, etc.

Nanotechnology is generally used for

i) constructing nano scale devices.
ii) functionalizing of nanoscale.
iii) controlling the properties by controlling size.
iv) synthesizing nano materials with controlled size distribution and surface structure.
v) increasing efficiency and decreasing price cost of the device.

Short Answer Questions [2 Marks]

1. What is nanotechnology? Explain.
2. The output of two-input AND gate is fed to a NOT gate. Give its logic symbol and write down its truth table. Identify the new logic gate formed.
3. Draw a circuit diagram for p-n junction diode in forward bias. Sketch the voltage versus current graph for it.
4. What is a logic gate? Give logic symbol and truth table for an OR gate.
5. What are logic gates? Give a truth table for a two input NOR gate.
6. The output of two-input AND gate is fed to a NOT gate. Draw the logic circuit of the combination of gates. Write down its truth table.
7. What is truth table? Write down the truth table for a two-input NAND gate.
8. What is a logic gate? Give logic symbol and truth table for a two-input AND gate.
9. What is doping? Discuss its significance in semiconductor studies.
10. When P and N type materials are interfaced, these exists a depletion layer at the interface. Explain.
11. A p-n diode conducts electricity when forward biased and does not conduct when reverse biased. Explain.
12. How is it possible to rectify an AC?